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CHEMICAL COMPOSITION OF BLACK ROCKFISH (*SEBASTES MELANOPS*) FILLETS AND BYPRODUCTS

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ABSTRACT

Black rockfish are important in the near shore fishery of Southeast Alaska, being the only species among the pelagic shelf rockfishes with a directed fishery in State waters. The purpose of this study was to determine the composition of black rockfish fillets, heads and livers. Fillet yields were low at 13.7% of whole fish weight (WFW), while heads and livers composed 24.8 and 1.9% of WFW, respectively. Byproducts were a valuable source of lipids, and the marine oils extracted from these tissues were similar in many aspects to oils from other cold water marine finfish, being rich in omega-3 and low in omega-6 fatty acids. Protein content of fillets, heads and livers were within the expected range (15–20%). Amino acid analysis revealed that byproducts protein fractions were of high nutritional value.

Results indicated that these byproducts have value and could be further processed into protein powders, fishmeal and fish oils.

PRACTICAL APPLICATIONS

This research is part of an ongoing effort to increase the value of Alaska fisheries by promoting entire utilization of the catch. There is opportunity to improve utilization of fisheries' byproducts by converting these materials into fishmeal, fish oils and protein powders that can either be used as ingredients for the manufacturing of feed further purified for food applications.

INTRODUCTION

Rockfishes are a diverse group of marine fishes. More than 30 species of the genera *Sebastes* (S.) and *Sebastolobus* are harvested from the Gulf of Alaska to the Bering Sea (Alaska Department of Fish and Game; Woodby *et al.* 2005). Yearly catches of all rockfish amount to approximately 50,000 tons and are worth about U.S.$11 million in the U.S. federal fishery (Woodby *et al.* 2005). The majority of the rockfish commercially caught in Alaska are either demersal shelf rockfish such as yelloweye rockfish (*S. ruberrimus*); slope rockfish such as Pacific Ocean perch (*S. alutus*), shortraker rockfish (*S. borealis*), rougheye rockfish (*S. aleutianus*), and northern rockfish (*S. polyspinus*); or pelagic shelf rockfish such as dusky rockfish (*S. variabilis; S. ciliatus*), widow rockfish (*S. entomelas*), yellowtail rockfish (*S. flavidus*), blue rockfish (*S. mystinus*) and black rockfish (*S. melanops*) (Woodby *et al.* 2005).

Black rockfish, also known as black snapper or black bass (California Department of Fish and Game – CDFG 2001), are found along the west coast of the U.S.A. from Alaska to California (Hart 1973). Among the pelagic shelf rockfish, fishery management in Alaska places emphasis in the black rockfish because this is the only species with a direct fishery in state waters (ADFG 2008). In a 5-year period (2000–2004), catches for black rockfish in Alaska averaged 260,455 kg with an ex-vessel value of $278,000 (Woodby *et al.* 2005). Black rockfish in Southeast Alaska can measure from 18 to 62 cm, become sexually mature at about 6–8 years of age, and are long-lived fish up to 49 years of age (ADFG 2008).

Little information exists about the quality and the chemical composition of black rockfish as food. Stansby (1976) reported that the edible flesh of black rockfish contained about 81% moisture, 19% protein, 2% lipids and 1% ash. Sawyer *et al.* (1984) evaluated the texture, appearance and flavor of black rockfish fillets and compared the sensory and instrumental measures with those of several snapper and rockfish species. Collins *et al.* (1980) evaluated the changes in physical, chemical and sensory properties of black rockfish when held in ice and carbon dioxide modified refrigerated seawater. Additional studies have evaluated quality, utilization and shelf life of a variety of rockfish species of the genera *Sebastes* (Bello and Pigott 1979; Kramer and Peters 1981; Davidovich and Pigott 1982; Reid *et al.* 1986; Wasson *et al.* 1991; Rehbein *et al.* 1994; Destura and Haard 1999; Yongsawatdigul and Park 2004); however, these studies did not include black rockfish.

Processing yields for black rockfish are relatively low with dressed head-on fish, headed and gutted fish, and skinless fillets yields ranging from about 85–91%, 48–62% and 25–33%, respectively (Crapo *et al.* 1993). Byproduct volume consists primarily of viscera and heads, which comprise up to 52% of the whole fish weight (Crapo *et al.* 1993). The composition of black rockfish byproducts, which could potentially be further processed into food and feed ingredients, as well as the fillets has not been reported. The objective of this research was to characterize the nutritional parameters of black rockfish fillets, heads and livers from fish commercially harvested from Alaska waters. This research is part of an ongoing effort to promote full utilization of Alaska fisheries resources by determining the nutritional value of fish fillets and its processing byproducts.

MATERIALS AND METHODS

Sampling

Five fresh black rockfish were troll caught in Kodiak (AK) in August 2007. The catch was immediately cooled on board in slurry ice and processed at the Fishery Industrial Technology Center pilot plant within 8 h. Processing yields were recorded with heads, livers and fillets being carefully removed and individually vacuum-packed (Nylon/PE vacuum bags of 100 μm film) using an UltraVac (Model UV2100-B, Koch, Kansas City, MO). Samples were frozen at −70C until analysis. All chemical analyses were conducted within 120 days from when the fish were harvested.

Proximate Analysis

Proximate composition was determined in duplicate for each of the 15 tissues. Moisture and ash content were determined using AOAC (AOAC 2007) methods #952.08 and #938.08, respectively. Nitrogen content was accessed by pyrolysis with a Leco FP-2000 nitrogen analyzer (Leco Co., St. Joseph, MO). Protein content was calculated as 6.25 times %N. Total lipid content was determined gravimetrically by the method of Folch *et al.* (1957). After lipid extraction, solvent was removed at 49C on a rotary evaporator (Büchi Rotavapor R-205, Westbury, NY) and lipids were transferred into a preweighed 10-mL amber screw top vial. The remaining solvent was removed under a N_2 gas stream until constant weight and percent lipids were determined. Oils were stored in chloroform containing 0.01% BHT at −70C until analysis.

Preparation of Fatty Acid Methyl Esters and Gas Chromatography Analysis

The fatty acid composition of the extracted oils was determined using the method described by Maxwell and Marmer (1983). Fatty acid methyl esters (FAMEs) were transferred into 1.5-mL snap-cap amber gas chromatography (GC) vials (Agilent Technologies, Wilmington, DE) and immediately analyzed. FAMEs were analyzed on a GC model 6850 (Agilent Technologies) fitted with a DB-23 (60×0.25 mm id., 0.25 μm film) capillary column (Agilent Technologies). An autosampler performed the GC injections of standards and sample, and injection volume was 1 μL. Data were collected and analyzed using the GC ChemStation program (Rev.A.08.03 [847]; Agilent Technologies 1990–2000). Chromatographic conditions were previously described (Bechtel and Oliveira 2006). Identification of peaks was performed using Supelco® (Bellefonte, PA) standards Marine Oil #1, Marine Oil #3, S189-19 and bacterial acid methyl esters mix. Samples were run in duplicates, and cod liver oil was used as a secondary reference standard (Ackman and Burgher 1965).

PAGE Electrophoresis

The sodium dodecyl sulfate tricine/polyacrylamide gel electrophoresis system was used with a Photodyne Foto/Force 300 apparatus under reducing conditions according to Schagger and Von Jagow (1987). Novex (Invitrogen Life Technologies) 10–20% precast tricine gels (Invertogen Inc., Carlsbad, CA) were used. The protein bands were visualized from the gels stained with Coomassie blue (Sigma-Aldrich, St. Louis, MO).

Mineral and Amino Acid Analysis

Fillets, heads and livers from four separate fish were analyzed for mineral and amino acid contents. Samples for mineral analysis were sent to the School of Natural Resources and Agricultural Sciences Palmer Research Center (Palmer, AK) for analysis. Samples were place in a furnace operated at 550C for 12 h. Ash residues were digested overnight in an aqueous solution containing 10% (v/v) hydrochloric acid and 10% (v/v) nitric acid. Digested solutions were diluted as needed and analyzed for P, K, Ca, Mg, S, Na, Cu, Fe, B, Co, Mo, Mn and

Zn by inductively coupled plasma optical emission spectroscopy on a Perkin Elmer Optima 3000 Radial ICP-OES (Waltham, MA).

Amino acid profiles were determined by the AAA Service Laboratory Inc., Boring, OR. Samples were hydrolyzed with 6N HCl and 2% phenol at 110C for 22 h. Amino acids were quantified using the Beckman 6300 analyzer (Beckman Coulter, Brea, CA) with post column ninhydrin derivatization. Tryptophan and cysteine content were not determined.

Statistical Analysis

The weighted means were derived from an analysis of variance run on Statistica version 8.0 (StatSoft Inc., Tulsa, OK). For tests of statistical significance between black rockfish tissues, data were subjected to Tukey's Honest Significant Difference test ($P < 0.05$).

RESULTS AND DISCUSSION

Processing Yields and Proximate Analysis

The processing yields are presented in Table 1. Black rockfish heads made up about 24.8% of whole fish weight (WFW), while skinless fillets constituted about 13.7% and livers, only 1.9% of WFW. The yields for heads and fillets were lower than the values previously published by Crapo *et al.* (1993). For the yelloweye rockfish, the %WFW for heads and livers were reported at 42.2 and 1.9%, respectively. Thus, livers of black rockfish make up similar proportion of whole body weight to livers of yelloweye rockfish; however, black rockfish heads make up a proportionally much smaller fraction of WFW than yelloweye rockfish heads (Oliveira *et al.* 2009). The moisture, protein, fat and ash content of black rockfish fillets, heads and livers on a wet tissue basis are listed in Table 1. The moisture (77.8%), protein (20.1%), lipid (0.9%) and ash (1.2%) contents of the black rockfish fillets were found to be in agreement with that of the Alaskan pollock fillets (82.3% moisture, 17.5% protein, 0.5% lipid, 1.1% ash) and Pacific cod fillets (82.3% moisture, 18.2% protein, 0.5% lipid, 1.3% ash) as determined by Bechtel (2003).

The black rockfish heads had proximate composition (Table 1) similar to yelloweye rockfish heads (72.2% moisture, 15.8% protein, 7.5% lipid, 4.5% ash) as previously reported by Oliveira *et al.* (2009). In Pacific ocean perch (*S. alutus*) heads, lipid (11%) and ash (6.7%) contents are higher than for the black rockfish, while moisture (67.7%) content is lower (Bechtel *et al.* 2009).The moisture and lipid content of black rockfish livers were found to be comparable with that of flathead sole (65.3% moisture, 24.9% lipid) and arrowtooth flounder (65.3% moisture, 19.4% lipid), as reported by Bechtel and Oliveira (2006). For yelloweye rockfish livers (Oliveira *et al.* 2009) and for Pacific Ocean perch viscera (Bechtel *et al.* 2009), the lipid content reported was 30.0 and 13.5%, respectively. The liver of black rockfish had protein content (15.1%) in the range of protein content found in livers of arrowtooth flounder (13.7%), Pacific halibut (13.4%), big mouth sculpin (18.4%) and pink salmon (18.6%) (Bechtel and Oliveira 2006). Ash content of black rockfish livers is low, as expected, and falls within the range of ash content determined for livers of the following species: yelloweye rockfish, big mouth sculpin, flat head sole, arrowtooth flounder, spiny head rockfish, pink salmon, walleye Pollock and Pacific halibut (Bechtel and Oliveira 2006; Oliveira *et al.* 2009), whose ash content ranged from 0.9 to 1.5%.

Comparing the different fish tissues, the ash content of black rockfish heads (4.6%) was higher than that of livers by almost fourfold, similar to the findings of Oliveira *et al.* (2009) for yelloweye rockfish. As expected, lipid content was significantly higher in liver, followed by heads and fillets and this is not surprising for rockfish species. Liver tissue is characterized by its high content of nutrients in both, protein and lipid fractions. Livers have a high fat content and are a good source of fish oil, with high levels of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). It is important to note that livers in rockfish are relatively small in size compared with percent weight values for walleye pollock or Pacific cod livers (Oliveira and Bechtel 2006). On the other hand, black rockfish heads have enough lipids (7.4%) available to spark interest in using this tissue in combination with the livers as raw material for the production of rockfish oil.

TABLE 1. AVERAGE FISH WEIGHT (kg ± SD), PROCESSING YIELDS (% WFW ± SD) AND PROXIMATE COMPOSITION (% ± SD) OF BLACK ROCKFISH FILLETS, HEADS AND LIVERS

Fish parts	Weight (kg)	Processing yield* (% WFW)	Lipids (%)	Ash (%)	Protein (%)	Moisture (%)
Fillets	0.43 ± 0.07	13.74 ± 0.79	0.91^{c} ± 0.16	1.23^{b} ± 0.02	20.11^{a} ± 0.26	77.75^{a} ± 0.36
Heads	0.62 ± 0.30	24.82 ± 3.66	7.39^{b} ± 0.82	4.60^{a} ± 0.27	17.46^{b} ± 0.61	70.55^{b} ± 0.49
Livers	0.05 ± 0.01	1.89 ± 0.20	20.01^{a} ± 1.65	1.27^{b} ± 0.05	15.14^{c} ± 0.37	63.58^{c} ± 1.36

* Whole fish weighed 2.46 ± 0.48 kg.
Different superscript letters show significant differences by column at $P < 0.05$.
SD, standard deviation of the mean; WFW, whole fish weight.

TABLE 2. FATTY ACID PROFILE (mg/g OIL ± SD) OF BLACK ROCKFISH FILLETS, HEADS AND LIVERS

Fatty acids	Fillets	Heads	Livers
14:0	22.32^{b} ± 1.81	40.76^{a} ± 2.13	12.23^{c} ± 1.28
Ante-iso 15:0	0.13^{b} ± 0.13	1.50^{a} ± 0.07	ND
15:0	1.64^{b} ± 0.26	2.99^{a} ± 0.12	0.26^{c} ± 0.16
16:0	100.10^{b} ± 5.81	127.11^{a} ± 2.01	73.06^{c} ± 5.25
Iso 17:0	3.48^{a} ± 0.46	5.36^{a} ± 0.39	7.09^{a} ± 2.73
Ante-iso 17:0	1.97^{b} ± 0.48	4.10^{a} ± 0.53	0.18^{c} ± 0.18
17:0	2.03^{a} ± 0.53	4.43^{a} ± 1.26	4.75^{a} ± 0.41
Ante-iso 18:0	2.11^{b} ± 0.71	5.22^{a} ± 0.16	ND
18:0	25.45^{a} ± 1.30	28.23^{a} ± 0.97	20.55^{b} ± 1.29
Σ Saturated FA (S)	*159.22^{b} ± 10.19*	*219.71^{a} ± 4.93*	*118.12^{c} ± 7.88*
16:1ω13 / 16:1ω11	2.95^{a} ± 2.44	2.75^{a} ± 0.09	0.22^{a} ± 0.22
16:1ω9	ND	1.23^{a} ± 0.37	0.99^{a} ± 0.65
16:1ω7	25.86^{b} ± 4.30	50.49^{a} ± 1.41	38.00^{ab} ± 6.38
16:1ω5	ND	1.61^{a} ± 0.47	4.09^{a} ± 1.66
17:1ω9	ND	1.24^{a} ± 0.32	0.85^{a} ± 0.54
18:1ω9 trans	4.63^{b} ± 0.72	6.10^{ab} ± 1.23	12.55^{a} ± 2.79
18:1ω9 cis	71.08^{b} ± 6.55	112.48^{a} ± 3.12	103.00^{ab} ± 6.13
18:1ω7	20.90^{a} ± 1.86	34.11^{a} ± 2.06	30.98^{a} ± 5.53
18:1ω5	2.58^{b} ± 0.38	4.05^{a} ± 0.56	2.78^{ab} ± 0.48
20:1ω11	25.07^{a} ± 2.48	36.89^{a} ± 6.38	24.09^{a} ± 4.14
20:1ω9	14.05^{b} ± 0.83	20.61^{a} ± 1.56	12.63^{b} ± 0.44
20:1ω7	0.30^{a} ± 0.30	2.39^{a} ± 0.98	0.68^{a} ± 0.68
22:1ω11	27.40^{ab} ± 3.10	40.64^{a} ± 7.08	18.63^{b} ± 3.61
22:1ω9	1.42^{b} ± 0.94	6.52^{a} ± 0.72	ND
24:1ω9	2.32^{a} ± 1.60	4.81^{a} ± 2.04	ND
Σ Monounsaturated FA	*198.87^{b} ± 15.29*	*325.92^{a} ± 17.00*	*249.91^{b} ± 23.50*
18:2ω6 cis	5.79^{b} ± 0.44	8.50^{a} ± 0.32	5.04^{b} ± 0.58
18:3ω3	2.34^{b} ± 0.72	5.12^{a} ± 0.13	1.39^{b} ± 0.80
18:4ω3	8.55^{b} ± 0.87	16.35^{a} ± 1.25	4.17^{c} ± 1.08
20:4ω6	5.36^{a} ± 0.20	6.02^{a} ± 0.42	2.15^{b} ± 1.02
20:4ω3	1.26^{a} ± 0.87	4.48^{a} ± 0.21	5.22^{a} ± 1.79
20:5ω3	66.81^{b} ± 9.29	99.24^{a} ± 8.14	44.27^{b} ± 5.59
22:5ω3	16.18^{a} ± 1.17	16.46^{a} ± 1.15	13.82^{a} ± 3.16
22:6ω3	144.56^{a} ± 3.24	92.08^{b} ± 4.37	47.75^{c} ± 3.55
Σ Polyunsaturated FA (P)	*250.85^{a} ± 15.12*	*248.25^{a} ± 12.11*	*123.81^{b} ± 13.91*
Σ Known FA	*608.64^{b} ± 37.20*	*793.51^{a} ± 7.21*	*492.04^{b} ± 40.81*
Σ Unknown FA	*1.83^{b} ± 0.71*	*6.45^{a} ± 1.19*	*8.10^{a} ± 3.70*
Σ ω3	239.70^{a} ± 14.89	233.73^{a} ± 12.10	116.62^{b} ± 12.88
Σ ω6	11.15^{a} ± 0.52	14.52^{a} ± 0.44	17.19^{b} ± 1.41
Ratio ω3:ω6	21.60^{a} ± 1.27	16.15^{a} ± 0.93	17.89^{a} ± 2.53
Ratio P:S	1.58^{a} ± 0.02	1.13^{b} ± 0.07	1.05^{b} ± 0.10

Different superscript letters show significant differences by row at $P < 0.05$.
SD, standard deviation of the mean; ND, not detected; FA, fatty acids.

Fatty Acids Profiles

The fatty acids (FA) of black rockfish fillets, heads and livers are reported in Table 2. The most abundant saturated fatty acid (SAT) in all of the tissues was palmitic acid (16:0), with heads having a significantly higher concentration of this FA while livers had the lowest. This trend was also reflected in the sum of SAT found in all three tissues. Palmitic acid was also the most abundant SAT found in Pacific Ocean perch heads and viscera, and also yelloweye rockfish heads and livers (Bechtel *et al.* 2009; Oliveira *et al.* 2009). The SAT in black rockfish fillets (159 mg/g oil or 26.1%) was in agreement with levels of SAT reported in giant grenadier (27.7%), arrow-tooth flounder (25.7%) and walleye pollock (27.6%) (Oliveira and Bechtel 2006). For heads, the palmitic acid content (127 mg/g oil) was slightly higher than that of pink salmon (12.4%), but similar to that of walleye pollock (16.8%) and Pacific Ocean perch heads (17.1%) (Bechtel *et al.* 2009; Oliveira and Bechtel 2005). The amount of palmitic acid and total SAT FA determined for black rockfish livers were in close agreement with the values obtained for livers of two other Alaska rockfish species, spiny head and yelloweye (Bechtel and Oliveira 2006; Oliveira *et al.* 2009).

Monounsaturated fatty acids (MUFA) were the most abundant class of FA for both black rockfish heads and livers. Oleic acid (18:1ω9 *cis*) was the predominant MUFA in all three tissues as it has also been observed for other northern rockfish species (Bechtel *et al.* 2009; Oliveira *et al.* 2009; Bechtel and Oliveira 2006). Oleic acid in black rockfish fillets (11.6%) is similar to levels determined for fillets of three other lean muscle northern marine fish species, walleye pollock (11.5%), Pacific cod (8.9%) and giant grenadier (11.1%) (Oliveira and Bechtel 2006). Oleic acid in black rockfish heads (14.1%) was higher to that of pink salmon heads (11.5%) and lower than in walleye pollock heads (18%), but quite similar to Pacific ocean perch values (Oliveira and Bechtel 2005; Bechtel *et al.* 2009). The concentration of oleic acid in black rockfish livers is in close agreement with the values reported for Pacific halibut (112 mg/g oil) but lower than values recorded for other northern rockfish livers such as yelloweye (180 mg/g oil) or spiny head (197 mg/g oil) (Bechtel and Oliveira 2006).

Polyunsaturated fatty acids (PUFA) values ranged from 124 to 251 mg/g oil for the black rockfish tissues analyzed. Most PUFA identified were in the ω3 form, with predominance of EPA and DHA, and this is typical for many of the northern pacific fish species. The EPA content in black rockfish was found to be highest in the heads (99 mg/g oil) and lowest in the livers (44 mg/g oil), and the difference was significant. Of interest was the high DHA concentration in fillets (145 mg/g oil) and lowest levels in livers (48 mg/g oil). In contrast, when taking into consideration the quantity of lipids present in the tissues, results would look very different when reported as mg of FA per 100-g tissue. In this case, because of the high content of lipids in livers, the EPA and DHA content would exceed values in the fillets as a percent of tissue weight. It is, nonetheless, interesting to notice the different ratios of EPA : DHA in the black rockfish tissues with fillets having a 1:2 ratio, while heads and livers have only a 1:1 ratio. The ratio of ω3 to ω6 was very high in fillets, when compared with the other two fish parts (Table 2). In lean fish muscle, the proportion of total lipid in the form of phospholipids is higher and the content of triglycerides is lower. Phospholipids from marine fish are abundant in long-chain ω-3 FA; thus, it is not surprising that black rockfish muscle, being much leaner than head and liver tissues, would have a higher ω3 to ω6 ratio.

Small quantities of 18:1ω9 *trans* were detected (less than 15 mg/g oil in all tissues analyzed) and this FA was significantly higher in livers as compared with fillets and heads. Interestingly, linoleic acid (18:2ω6) in the *trans* configuration was not detected in any of the samples. In general, the extracted oils from black rockfish fillets, heads and livers were of high nutritional value but lower conversion of FA to methyl esters was observed for black rockfish livers when compared with fillets and heads. Liver tissue tends to have higher enzymatic lipolysis activity, which could explain lower amount of saponifiables extracted. Notwithstanding, the extracted oils from the tissues studied were similar in many aspects to oils from other cold water marine finfish species, having an abundance of FA of the ω-9 and ω-3 kind, with few ω-6 FA. Consuming 100 g of black rockfish fillets provides only 1 g of fat; however, about 240 mg of that is in the form of ω-3s, and this value is roughly one-third of the recommended daily intake of 650 mg suggested by Katz and Nettleton (2003).

Amino Acids Profiles

The amino acid profiles of the black rockfish fillets, heads and livers are listed in Table 3. The amino acid analysis included the standard 16 amino acids that were determined by acid hydrolysis of the samples and post-column ninhydrin derivatization of the separated amino acids. The value ranges for three of the potentially limiting amino acids were 3.5–3.7% for methionine, 8.1–10.5% for lysine and 4.6–5.0% for threonine. Black rockfish livers had the highest values for methionine and threonine, while the fillets had the highest values for lysine. The proline content of the black rockfish livers (4.8%) was similar to values for other fish livers and lower than values found in heads, which contain large amounts of connective tissue with a hydroxyproline value of 1.7%. The amino acid profile of black rockfish heads was similar to that of Pacific Ocean perch heads (Bechtel *et al.* 2009), while black rockfish livers had amino acid profiles similar to yelloweye rockfish

TABLE 3. AMINO ACID PROFILE OF BLACK ROCKFISH FILLETS, HEADS AND LIVERS (% OF TOTAL AMINO ACIDS ± SD)

Amino acids	Fillets	Heads	Livers
ALA	$5.55^{b} \pm 0.07$	$6.13^{a} \pm 0.13$	$6.00^{a} \pm 0.30$
ARG	$6.85^{a} \pm 0.31$	$7.19^{a} \pm 0.22$	$5.78^{b} \pm 0.61$
ASP	$10.58^{a} \pm 0.26$	$9.54^{b} \pm 0.19$	$9.15^{b} \pm 0.24$
GLU	$15.62^{a} \pm 0.57$	$13.51^{b} \pm 0.36$	$13.35^{b} \pm 0.50$
GLY	$3.78^{b} \pm 0.11$	$7.79^{a} \pm 0.63$	$5.90^{a} \pm 1.67$
HIS	$2.85^{ab} \pm 0.19$	$2.50^{b} \pm 0.15$	$3.02^{a} \pm 0.27$
HYP	ND	$1.70^{a} \pm 0.56$	$0.43^{b} \pm 0.86$
ILE	$4.84^{a} \pm 0.06$	$4.11^{b} \pm 0.24$	$4.48^{ab} \pm 0.37$
LEU	$8.53^{a} \pm 0.07$	$7.05^{b} \pm 0.28$	$7.95^{a} \pm 0.54$
LYS	$10.47^{a} \pm 0.18$	$8.12^{b} \pm 0.30$	$8.09^{b} \pm 0.41$
MET	$3.65^{a} \pm 0.08$	3.47 ± 0.21	3.72 ± 0.29
PHE	$4.76^{b} \pm 0.09$	$4.55^{b} \pm 0.29$	$5.48^{a} \pm 0.46$
PRO	$3.10^{b} \pm 0.19$	$5.17^{a} \pm 0.38$	$4.79^{a} \pm 0.99$
SER	$3.56^{b} \pm 0.18$	$4.50^{a} \pm 0.24$	$4.48^{a} \pm 0.16$
THR	4.67 ± 0.10	4.55 ± 0.36	$4.9^{a} \pm 0.33$
TYR	$4.22^{ab} \pm 0.04$	$3.86^{b} \pm 0.22$	$4.51^{a} \pm 0.43$
VAL	$6.96^{b} \pm 0.06$	$6.27^{c} \pm 0.20$	$7.90^{a} \pm 0.55$

Mean values and standard deviation (SD) of the mean.
Different superscript letters show significant differences by row at $P < 0.05$.
ND, not detected.

livers (Oliveira *et al.* 2009) and spiney head rockfish livers (Bechtel and Oliveira 2006). Because of cost constraints, separate determinations for tryptophan, using the base hydrolysis procedure, and cysteine as cysteic acid after oxidation with performic acid were not performed. Although tryptophan is an essential amino acid for humans, there is a lack of literature values for fish liver. Tryptophan values of 1.1% of total protein have been reported for rock fish muscle, and 1.3% of total protein for raw beef liver (U.S. Department of Agriculture, Agricultural Research Service, USDA Nutrient Data Laboratory 2007). Regarding cysteine content, it is noteworthy to point out that this is not an essential amino acid for humans; nonetheless, cysteine content for Pacific Ocean perch muscle was reported at 1.1% of total protein, while higher levels at 1.8% of total protein were determined for raw beef liver (U.S. Department of Agriculture, Agricultural Research Service, USDA Nutrient Data Laboratory 2007). Overall, the amino acid profiles in Table 3 had high levels of essential amino acids.

Electrophoresis Analysis

Figure 1 depicts a representative electrophoresis gel showing the protein band profiles for black rockfish. As expected, the protein band profile from fillet was consistent with large amounts of the myosin at about 200 kDa, actin about 40 kDa and bands of other abundant proteins. The banding profile for the head had common bands with those in the fillet sample, which would be expected as there is a lot of muscle tissue found in the head. There are additional protein bands in the gel lane of the head sample that are not apparent in the fillet gel lane. The electrophoresis profiles of black rockfish head, fillet and liver are shown in Fig. 1. The liver protein profile exhibited protein bands with molecular weights ranging from 13 to 110 kDa and is similar to what was seen for other cold water marine fish livers (Bechtel and Oliveira 2006).

Mineral Content

The mineral contents of black rockfish fillets, heads and livers are listed in Table 4. As expected, black rockfish heads with higher bone (ash) content contained much higher amount of Ca and P (Ca/P ratio of 1.7) than fillets and livers. Interestingly, Pacific Ocean perch heads have much higher Ca (6.3%) and content than black rockfish heads (Bechtel *et al.* 2009). The low level of Ca (0.02%) and average levels of P (0.63%) in the black rockfish livers were similar to what was observed in the livers of other cold water marine fish species such as yelloweye rockfish (0.02% Ca, 0.44% P) (Bechtel and Oliveira 2006; Oliveira *et al.* 2009). The percent K was significantly higher in fillet than the other two tissues. Black rockfish livers like livers form other marine fish are good sources of Fe (890 ppm), Zn (96 ppm) and Cu (11 ppm) (Bechtel and Oliveira 2006).

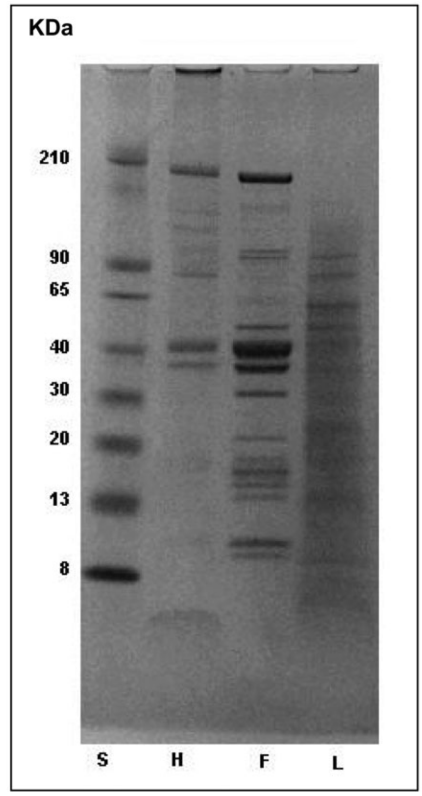

FIG. 1. ELECTROPHORESIS PROFILES OF THE LIVER PROTEIN FROM BLACK ROCKFISH: LANE 1, SDS MARKER PROTEINS; LANE 2, BLACK ROCKFISH HEAD; LANE 3, BLACK ROCKFISH FILLET; LANE 4, BLACK ROCKFISH LIVER

CONCLUSION

Heads of black rockfish are large and contributed over 25% of WFW. Livers contained high levels of lipids (20%) but were of small size (2% of WFW). Oils extracted from all black rockfish tissues studied were abundant in ω-3 FA, with a much lower content of ω-6 FA. Black rockfish livers were a good source of fish oil, rich in marine fatty acids such as DHA and EPA. Black rockfish heads had relatively high lipid content, which was 24% ω-3 together with a high DHA/EPA ratio of 1:1. Amino acid analysis revealed profiles similar to other cold water fish species characterized by protein with high levels of essential amino acids. Results indicated that black rockfish heads and livers can be utilized for the production of high-quality specialty ingredients that can either be incorporated in animal feed formulations, or undergo further purification for nutraceutical and food ingredient uses.

TABLE 4. MINERAL COMPOSITION OF BLACK ROCKFISH FILLETS, HEADS AND LIVERS (DRY WEIGHT BASIS ± SD)

Minerals	Unit	Fillets	Heads	Livers
Ca	%	0.03[b] ± 0.01	2.78[a] ± 1.13	0.02[b] ± 0.02
K		1.43[a] ± 0.12	0.71[b] ± 0.04	0.64[b] ± 0.09
Mg		0.11[a] ± 0.01	0.08[b] ± 0.01	0.04[c] ± 0.01
P		0.71[b] ± 0.05	1.61[a] ± 0.56	0.63[b] ± 0.07
S		0.89[a] ± 0.03	0.72[b] ± 0.03	0.82[ab] ± 0.07
B	ppm	<0.01	<0.01	<0.01
Co		<0.15	<0.15	<0.15
Cu		ND	0.21[b] ± 0.08	10.68[a] ± 4.78
Fe		7.75[b] ± 1.26	195.25[a] ± 147.37	889.75[a] ± 624.08
Mo		1.5[a] ± 2.0	<0.15[b]	<0.15[b]
Mn		<1	<1	<[a]
Na		678.75[b] ± 42.00	2369.25[a] ± 497.50	889.00[b] ± 151.38
Zn		11.00[c] ± 2.58	52.75[b] ± 6.18	96.25[a] ± 4.86

Mean values and standard deviation (SD) of the mean.
Different superscript letters show significant differences by row at $P < 0.05$.
ND, not detected.

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